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Fine-tuning as Old Evidence, Double Counting, and the Multiverse

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ABSTRACT

The idea that there might be multiple universes with different parameters of nature is often considered an attractive response to the finding that various parameters appear to be delicately fine-tuned for life. The present paper investigates whether the appeal to fine-tuning can legitimately be combined with an appeal to independent empirical evidence for other universes or whether, as suggested by Cory Juhl, combining such appeals inevitably results in illegitimate *double counting* of the finding that the parameters are right for life. In doing so, the paper takes into account the fact that the parameters' life-friendliness is old evidence for us, which makes Bayesianism's problem of old evidence relevant to Bayesian analysis of its evidential impact. Ultimately, the verdict reached is that the warning of double counting is helpful, but that double counting can in principle be avoided. The paper highlights remaining independent challenges against the fine-tuning argument for the multiverse.

1. Introduction: Why the Multiverse?

According to the multiverse hypothesis, there are multiple universes, some of them radically different from our own. Many physicists and at least some philosophers are attracted to this hypothesis because they regard it as offering a promising response to the perennial puzzle that many parameters of nature appear to be *fine-tuned for life*: had they been even slightly different, life could not possibly have existed. For example, had the difference between the masses of the two lightest quarks, the up-quark and the down-quark, been slightly different, the stability of the proton and the neutron, which are bound states of these quarks, would have been affected (Carr and Rees 1979; Hogan 2000, section 4; Hogan 2007). This would have likely resulted in a much simpler and less complex universe where bound states of quarks other than the proton and neutron dominate. Life would also not have appeared, as it seems, if the mass of the electron, which is roughly 10 times smaller than the mass difference between the down- and up-quark, had been somewhat larger in relation to that difference. Fine-tuning of the lightest quark masses with

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respect to the strength of the weak force has been found as well (Barr and Khan 2007). Further suggested instances of fine-tuning concern the strength of gravity, the strength of the strong and weak nuclear forces (when measured against that of electromagnetism as a reference), the vacuum energy density, the overall energy density of the universe in its very early stages, the relative amplitude of energy density fluctuations in the very early universe, the initial entropy of the universe, and the form of the known laws of nature itself.¹

The finding that life requires finely tuned parameters has been cited as support for the idea of divine creation (e.g. Swinburne 2004; Collins 2012), but the multiverse idea may offer an attractive non-theistic alternative: if there is a sufficiently diverse multiverse where the parameters vary between universes, it is only to be expected that there is at least one universe where they are right for life. Trivially, observations can only be made where the parameters are right for life,² and the multiverse inhabitants—if there are any—will unavoidably measure apparently fine-tuned parameters. According to this line of thought, the multiverse idea may remove the puzzle of why we exist despite the required fine-tuning of the parameters and, derivatively, why we find the parameters fine-tuned for life.

This paper assesses a specific worry about belief in the multiverse as based on this *fine-tuning argument*: that such belief would inevitably rely on illegitimate *double counting* of the fine-tuning evidence and would hence be irrational (Juhl 2007). Double-counting, to use an example by Juhl (2007, 554f.), occurs when a prosecutor in court first appeals to the fact that some person's fingerprints are on the murder weapon to argue that we should seriously consider the possibility that she might be the murderer and then argues that, in view of the fact that her fingerprints are on the murder weapon, we should now become more confident that she really is the murderer. It is uncontroversial that such double counting is fallacious. According to Juhl, it is committed by any attempt to run the fine-tuning argument for the multiverse in combination with purportedly independent empirical support for the multiverse. The problem that he sees is that any suggested independent empirical evidence for a multiverse—in virtue of having been obtained in this (life-friendly) universe—would likely entail that the parameters are right for life here. If that is the case, appealing to fine-tuning in addition to further empirical evidence does indeed amount to double counting of the evidence that the parameters are right for life despite the required fine-tuning.

In a nutshell, the double counting charge comes down to the following dilemma for proponents of the multiverse: either they rely on the fine-tuning argument, but then they have to accept that there are no good independent reasons for taking the multiverse hypothesis seriously in the first place; or they insist on having a solid independent motivation for the multiverse hypothesis, but then they are no longer able to run the fine-tuning argument. If the dilemma is correctly diagnosed, the case for (or against) the multiverse may be doomed to remain inconclusive forever—or at least as long as we do not have overwhelming independent evidence for (or against) a multiverse that renders the appeal to fine-tuning obsolete.

The double counting worry can be formulated succinctly when set up as an objection against the fine-tuning argument for the multiverse in its Bayesian formulation, using subjective probabilities. The assessment of this formulation is complicated, however, by the fact that, as pointed out by Monton (2006), Leeds (2007), and Collins (2012), the fine-tuning of the parameters is inevitably *old evidence* for us: that the parameters are right for life is something that we have long known, even if we may assess the fine-tuning's

rational significance only now. This means that to properly investigate the double counting charge in Bayesian terms, we must, at least provisionally, adopt some solution to Bayesianism's long-standing *problem of old evidence* (Glymour 1980). Following Monton's track (and, similarly, that of Collins 2012, section 4.3), this paper adopts Colin Howson's so-called *ur-probability solution* (Howson 1991). Based on it, the verdict reached is that double counting of the fine-tuning evidence is indeed a potential issue which, however, can in principle be avoided. On the way to this verdict, the paper highlights independent challenges against the fine-tuning argument for the multiverse that remain.

2. The Fine-tuning Argument for the Multiverse and its Criticisms

The argument from fine-tuning for the multiverse is frequently formulated in Bayesian terms, using subjective probability assignments, and it is in the context of the Bayesian formulation that the double counting charge can be neatly raised.³ An elementary version of the Bayesian formulation has the form of a comparison of our rational credences in a single-universe hypothesis U and a rival multiverse hypothesis M . (In terms of notation, the present exposition broadly follows Bradley 2009.) According to U , there is only a single universe with the same values of the parameters throughout space and time; according to M , there are many universes with wildly differing values of the parameters across universes.⁴

For the sake of simplicity and ease of exposition, we make the simplifying assumptions that U and M are both sharply defined and the only hypotheses that deserve serious consideration. Furthermore, we assume that the fine-tuning evidence R (' R ' for 'right') to be considered is that, despite the required fine-tuning, there is at least one universe with the right parameters for life. There are serious criticisms of these assumptions, as discussed further below.

Let us consider the rational impact of the finding R that the parameters are right for life on our credences with respect to U and M . According to standard Bayesian conditioning, our posteriors after taking R into account are given by our prior conditional credences $P(M | R)$ and $P(U | R)$. By Bayes' theorem, their ratio is

$$\frac{P(M | R)}{P(U | R)} = \frac{P(R | M) P(M)}{P(R | U) P(U)}. \quad (1)$$

Centred around this equation, the fine-tuning argument proceeds as follows: if the multiverse according to M is sufficiently vast and varied that life will unavoidably appear at least *somewhere* in it, the conditional prior $P(R | M)$ receives a value close to 1. In contrast, inasmuch as life-friendly values require delicate fine-tuning, the conditional prior $P(R | U)$ will receive a value close to 0. Since $P(R | M) \gg P(R | U)$, thus established, entails $P(R | M)/P(R | U) \gg 1$, the ratio of posteriors is much larger than the ratio of the priors, i.e. $P(M | R)/P(U | R) \gg P(M)/P(U)$. Thus, according to this line of thought, the evidence R strongly supports M over U . Unless our priors dramatically favour the single universe over the multiverse in that $P(U) \gg P(M)$, our posteriors strongly favour the multiverse over the single universe. Accordingly, the argument concludes, our credence in the multiverse should be high.

That this argument remains controversial is unsurprising because it can be criticised at every step. For example, one may doubt whether it is indeed legitimate to consider only one single-universe hypothesis U and one multiverse hypothesis M in the absence of a

well-developed and well-structured hypothesis space. Next, it is unclear whether we should really be perplexed by the finding that the parameters are right for life absent, for example, some physically well-motivated probability distribution over possible values of the parameters which would give us good reasons to indeed ascribe a minuscule value to $P(R|U)$.⁵ Perhaps some or even many of the apparently fine-tuned parameters had to have their actual values due to basic physical reasons that we presently do not understand.

What makes the argument in the above form even more problematic is that R —that the parameters are right for life in at least one universe—is not the complete fine-tuning evidence that we possess. In fact, it is incomplete in at least two respects: first, as pointed out e.g. by White (2000), Bostrom (2002), Bradley (2012), and Landsman (2016), our full evidence includes not merely R but O : that the parameters are right for life in *our* (i.e. *this*) universe. Does the argument survive if R is replaced by O ? Some philosophers argue that it doesn't in that, as they contend, it is fallacious to 'suppos[e] that the existence of many other universes makes it more likely that *this* one [is] life-permitting' (White 2000, 263; see also Hacking 1987, Draper, Draper, and Pust 2007, Leeds 2007, and Landsman 2016). The fallacy that the inference from fine-tuning to the multiverse commits according to these authors is the one that Hacking (1987) has dubbed the *inverse gambler's fallacy*. Other philosophers disagree with this diagnosis (Leslie 1988; McGrath 1988; Bostrom 2002; Holder 2002; Manson and Thrush 2003; Juhl 2005, 2007; Bradley 2009), arguing that it overlooks an observation selection effect which, when taken into account, ultimately renders the argument valid after all. Settling that debate is beyond the scope of this paper. Acknowledging that the inverse gambler's fallacy charge remains as a potential stumbling block, I will content myself to considering the version of the fine-tuning argument reviewed above and assume—as a working hypothesis—that the replacement of R by O does not render it invalid.

The second respect in which R is not the complete fine-tuning evidence is that we know the values of the parameters with higher accuracy than R says. For example, the value of the cosmological constant is known to be roughly $\Lambda = 1.3 \times 10^{-123}$ (in units where the velocity of light and Planck's constant \hbar are 1). This value is evidently compatible with the existence of life, but so are values two or three orders of magnitude larger (Schellekens 2013, section III.E.3). There is a broad consensus in the literature on multiverse cosmology that specific multiverse theories are to be regarded as empirically disconfirmed if, according to them, the values of the parameters that we measure are of *atypical* order of magnitude compared with the values measured by cosmic observers. Making the typicality criterion precise is difficult,⁶ though, notably because it is not always clear which reference class of observers to use.⁷

3. Fine-tuning as Old Evidence

We have long been aware that the parameters are right for life in our universe, plausibly as long as we have entertained the notion of laws and constants of nature at all. Accordingly, the evidence R (or O)—that the parameters are right for life—is, strictly speaking, *old evidence* for us. Troublingly for the proponent of the fine-tuning argument for the multiverse, this means that succinctly staging the argument in Bayesian terms requires operating in the framework of some solution to Bayesianism's problem of old evidence (Glymour

1980). Often this complication is ignored—perhaps understandably, because that problem has no widely accepted solution. However, as suggested by Monton (2006) and Collins (2012), the so-called *ur-probability* solution to the problem of old evidence has the potential to provide a framework for staging Bayesian versions of fine-tuning arguments, whether for God or the multiverse. Applying this solution effectively allows us to preserve the above formulation of the fine-tuning argument for the multiverse (modulo the complications related to criticisms discussed there), while coherently taking into account the fact that R is old evidence.

The basic idea of the *ur-probability* solution, also known as the counterfactual solution and advocated notably by Colin Howson (1991), is to obtain some rational probability function P^+ that takes the old evidence E properly into account by considering a hypothetical situation where E is not available, assuming that E is acquired, and then performing ordinary Bayesian conditioning with respect to E . In the version of the *ur-probability* solution used by Monton, one first considers an agent whose hypothetical epistemic situation resembles our own as closely as possible with the sole exception that she lacks the old evidence E whose impact we are trying to assess. The probability function that supposedly captures the epistemic agent's credences in that situation is sometimes called an *ur-prior* P . This term may create some confusion, however, by evoking the image of an epistemic 'ur-situation' where no empirical background information whatsoever is available. To avoid any misunderstanding, I will speak of the probability function P as *hypothetical prior*. Its assignment is typically based on a rather substantive body of empirical background evidence—namely, everything that coherently remains of our complete evidence once we have subtracted information about whether E .

The epistemic agent's credences *after* having properly taken into account E , correspond to our looked-for posterior P^+ . They are obtained from the hypothetical prior via standard Bayesian conditioning $P^+(H) = P(H | E)$ for any hypothesis H . Crucially, the hypothetical prior P may differ from the real prior P^- , which expresses our *actual* credences before we systematically assess the impact of E . If, for some reason, the hypothetical prior is identical to the real prior, i.e. if $P^- = P$, the update rule reduces to ordinary Bayesian conditioning $P^+(H) = P^-(H | E)$, but in general this identity does not hold.

The *ur-probability* solution to the problem of old evidence allows us to rescue—with minimal damage—the Bayesian formulation of the fine-tuning argument for the multiverse in view of the insight that R is old evidence. The only adjustment required is that one interpret P as a hypothetical prior rather than actual prior. Crucially, this means that $P(M)$ and $P(U)$ may not in any way reflect awareness of the evidence R because R 's evidential impact is supposed to be captured by Bayesian conditioning alone. Somewhat oddly, a hypothetical agent with credences $P(M)$ and $P(U)$ would have to be one whose evidence, on the one hand, resembles the total evidence that we have as strongly as possible while, on the other hand, it should not include the fact that the parameters are right for life. Consequently, this hypothetical agent would have to be one who (at least temporarily) is unaware of her own existence. Admittedly, this is a strange requirement to make, and it dramatically reflects a more general drawback of the *ur-probability* solution, namely, that it can be very difficult to specify reasonable hypothetical priors. Monton, who refers to hypothetical probabilities as *ur-probabilities*, acknowledges this by conceding that 'it is not always clear what values the *ur-probabilities* should take,

especially when one has to make extreme modifications to one's opinion, by, for example, supposing that one does not fully believe that one exists' (Monton 2006, 416).

This drawback is severe,⁸ and some may argue that it undermines the application of the ur-probability solution to fine-tuning arguments. However, there seems to be no alternative way of rescuing the fine-tuning argument for the multiverse in anything resembling its standard Bayesian formulation reviewed in section 2 (other than simply ignoring the fact that fine-tuning is old evidence), so operating on the basis of the ur-probability solution seems to be the best among various unattractive choices. Fortunately, as we shall see, considerations about priors will in the end 'drop out' of the discussion of double counting that follows. This may alleviate concerns about the intelligibility of the imagined epistemic situation where an agent is pictured as unaware of her own existence.

4. Motivating a (Hypothetical) Prior for the Multiverse?

Rational belief in a multiverse as based on the fine-tuning argument for the multiverse requires having a solid motivation for a non-negligible hypothetical prior $P(M)$. To appreciate this, it is useful to consider the *special design* hypothesis (*SD*), which states that our universe is the product of a very powerful and intelligent creator fixated on creating a universe *exactly like ours* (i.e. with physical, chemical, biological, geographical, social, psychological further details all precisely as in our universe). Given this design of *special design*, our conditional credence $P(R | SD)$ should be 1. A hypothetical 'fine-tuning argument for special design', analogous to the fine-tuning argument for the multiverse outlined above, would seem to give us a very strong case for *SD*. The reason why we may nonetheless not believe in *SD* is that it seems (or at least may seem) ad hoc, contrived, and devoid of independent motivation.⁹ Formally, this may be expressed by saying that any reasonable hypothetical prior $P(SD)$ will reasonably be minuscule. In fact, it may well be so tiny that even after taking into account all our 'confirming' evidence for *SD*, notably the evidence *R*, our posterior $P^+(SD)$ will still be negligible.¹⁰

Perhaps the multiverse hypothesis *M* is similarly contrived and devoid of independent motivation as the special design hypothesis! Lacking a compelling argument to the contrary, even if the finding that the parameters are right for life does turn out to confirm the multiverse hypothesis over a rival single-universe hypothesis (i.e. even if the criticisms outlined in section 2 can be overcome), its outcome may not be rational confidence in the multiverse but only some degree of belief that, though larger than any rational hypothetical prior $P(M)$, is still negligibly small. The example of *SD* suggests that proponents of the fine-tuning argument for the multiverse should have a good case for a non-negligible hypothetical prior $P(M)$.

According to Juhl, however, there are principled reasons for believing that there can be no such case:

One worry that I have about an argument for an actual multiverse is that such an argument would have to somehow convince us that the prior probability $P(M)$ of a multiverse hypothesis is high enough on any reasonable probability assignment to warrant assigning it a high posterior (higher than 1/2, say). I do not foresee a convincing a priori argument for this, either on the basis of principles of indifference, or on the basis of a rationally compelling 'logical' approach to assignments of priors. But if we try to assign rational 'prior' probabilities on an a posteriori basis of empirical evidence, as a means of avoiding 'purely a priori'

approaches and their attendant difficulties, then we might find it difficult to avoid a problem to be described below The problem might be called a fallacy of (evidential) ‘double dipping’. (Juhl 2007, 554)

What would be an ‘a priori argument’ for a non-negligible (hypothetical) prior $P(M)$? One could try an appeal to simplicity or elegance in favour of the ‘world ensemble’ hypothesis (Carter 1974, 295), according to which all mathematically possible combinations of values of the parameters that appear in the laws of our universe are realised, each in at least one universe. However, in view of the highly speculative character of such stipulations it seems wise to accept Juhl’s sceptical attitude and rather focus on attempts to obtain a well-motivated $P(M)$ based on, as he calls it, ‘an a posteriori basis of empirical evidence.’ Why is Juhl pessimistic about such attempts as well?

Let us look at a *prima facie* attractive way of motivating a non-negligible $P(M)$ ‘on an a posteriori basis’, namely, by developing, testing, and empirically confirming some fundamental physical theory T , e.g. about elementary particles, fields, and their interactions, which, as a ‘side effect’, suggests or entails the existence of multiple universes. One way for a theory T to have this feature would be by suggesting a physical mechanism of how multiple universes with different parameters are dynamically generated. There seems to be no reason why it should be impossible in principle to acquire empirical data in our universe that suggest such a theory T . And any data D that we might possibly gather in support of T would then indirectly support the multiverse hypothesis M in the form suggested by T —over and above the support that, according to the fine-tuning argument, M receives from R . And, as it seems, one way of taking this independent support for M into account would be by choosing a non-negligible hypothetical prior $P(M)$ that reflects the impact of D via T .

In fact, the idea of a fundamental physical theory T that is multiverse-friendly in the required sense is not mere fiction. According to many contemporary physicists, we do have such a theory, in the form of the combination of *inflationary cosmology* and *string theory*, two intensely pursued theoretical frameworks of cosmology and high energy physics, respectively.¹¹ For the sake of concreteness, it is useful to outline how these two theories, when combined, are taken to suggest a concrete multiverse scenario, the so-called *landscape multiverse* (Susskind 2005).¹²

Inflationary cosmology, which is currently the dominant theoretical framework of early universe cosmology, states that the early universe expands (near-) exponentially fast, resulting in causally isolated space-time regions, so-called ‘island universes’. Importantly for our present interests, according to many dynamical models of inflation this process is ‘eternal’ in that the formation of island universes never ends. As a result of this process, a vast (and, according to most models, infinite) ‘multiverse’ of island universes is continually being produced (Guth 2000). If we add the perspective of string theory to this picture, it becomes plausible that the parameters may vary between island universes. The reason for this is that string theory, one of the leading approaches to unify our best theories of particle physics and gravity, has an enormous variety (‘landscape’) of lowest energy states or *vacua*.¹³ If string theory is correct, different vacua manifest themselves at the level of observations and experiments in terms of different higher-level physical laws and different values of the constants. Thus, when combined, inflationary cosmology and string theory suggest a cosmological picture in which there are infinitely many island

universes in which all different string theory vacua—corresponding to different higher-level physical laws and constants—are actually realised in the different island universes. If, as is widely believed, this landscape multiverse includes a universe with the same higher-level laws and constants as our own, it is a candidate multiverse scenario in the sense of the fine-tuning argument.

Both inflationary cosmology and string theory are at present speculative to a significant degree. Inflationary cosmology has some relatively direct empirical support in the form of its multiply confirmed, very precise predictions of the shape of the cosmic microwave background (CMB) fluctuations, as recently measured with unprecedented accuracy by the PLANCK satellite (Planck Collaboration 2014).¹⁴ But there is no direct empirical evidence for string theory at all, and not even the theory's most ardent advocates seem to expect such evidence for the next few decades. However, what matters for the more principled purposes of this paper is what this example illustrates: at least apparently, empirical evidence for the combination of inflationary cosmology and string theory might help us motivate a non-negligible $P(M)$.

5. The Double-counting Charge Stated

Juhl acknowledges that theories such as inflationary cosmology and string theory might independently suggest some version of the multiverse hypothesis. He does not think, however, that they can be used to motivate a non-negligible $P(M)$, due to a difficulty related to double counting ('double dipping', as he calls it):

I do not foresee a plausible scenario in which what I call the 'prior' of the existence of the law or mechanism for universe production can be rationally constrained to be reasonably high, without that 'prior' itself depending on evidence entailing the existence of a universe much like ours. To make clear what I have in mind here, suppose that physicists come up with a 'unified theory of everything' $[T]$ ¹⁵, which entails that the existence of a multiverse has a probability of around 1/2. How will they discover such a theory? Surely $[T]$ will be obtained via observations of goings-on within our universe. Such goings-on will entail the existence of our universe, that universe of which they are parts, or within which they are events. But if such events form the evidential basis for assigning a not-too-low probability to a theory M of multiverse production, then we cannot reuse or 'double dip' that same evidence, the existence of our universe, to provide further support to the theory. (Juhl 2007, 555)

The gist of this passage is that any observational data D that we might collect in support of some multiverse-friendly theory T will unavoidably entail the finding R according to which the parameters are right for life in some universe. Juhl's argument is deceptively simple: any data D that we might collect will unavoidably be about 'goings-on within our universe'; goings-on within our universe unavoidably 'entail the existence of our universe'; and, since our universe has the right parameters for life, its existence entails the existence of a universe where the parameters are right for life, i.e. it entails R . And if any D indeed entails R , then basing one's prior $P(M)$ on D means implicitly using R in that step. Accordingly, using R when running the fine-tuning argument to boost our credence in M would mean using R *again* and would hence mean illegitimate double counting of R .

Juhl is adamant that the double counting charge goes beyond highlighting that the fine-tuning argument in its Bayesian formulation must come to terms with the problem of old

evidence. It is useful, though, to frame the double counting charge in the language of the ur-probability solution, where it amounts to the worry that no empirical evidence whatsoever can be relevant when assessing $P(M)$, construed as a hypothetical prior. According to Juhl, data D that are potentially relevant to our credence in M —since they are from *our* universe—are likely to entail that the parameters are right for life in that universe. But this means that they cannot possibly be available to an epistemic agent in the hypothetical situation invoked by the ur-probability solution, who, by assumption, is unaware that the parameters are right for life. If Juhl is right, it is in principle impossible to motivate *any* chosen value for the hypothetical prior $P(M)$ by appeal to empirical evidence, notably any non-negligible value.

Is it plausible, if we look at the example of the landscape multiverse outlined in the previous section, that multiverse-supporting empirical data will inevitably entail R : that the parameters are right for life? Prima facie it may seem quite realistic. The CMB data, for example, which support inflationary cosmology and thereby (indirectly) the landscape multiverse, may indeed entail at least large bits of the evidence R according to which the parameters are right for life: the CMB radiation is electromagnetic, so a detailed description of it will include information about the values of the constants associated with electromagnetism. Moreover, a detailed account of *how* an early inflationary phase—if it occurred—resulted in CMB fluctuations as detected today will inevitably rely on auxiliary assumptions concerning other fundamental interactions that have shaped our universe in the meantime. As a consequence, the constants associated with other interactions—the weak and strong nuclear interactions and gravity—are likely to be significantly constrained, and thus in part entailed, by such an account as well.

To sum up, Juhl's worry that empirical data that favour a multiverse cosmology will entail that the parameters are right for life (or at least significant parts of it) deserves being taken seriously. But if Juhl is correct, multiverse proponents who rely on the fine-tuning argument face a dilemma: they can either run the fine-tuning argument, but without relying on a well-motivated non-negligible (hypothetical) prior $P(M)$ (thus potentially ending up in a similar situation as those who run the fine-tuning argument for *special design* without having a good independent case for a non-negligible hypothetical prior $P(SD)$); or they can make a well-founded assignment of $P(M)$ based on observational data D (perhaps indirectly via appeal to empirical support for some multiverse-friendly theory T), but then they are no longer able to run the fine-tuning argument without counting R twice because D inevitably entails R . In the following, final, section I explore how multiverse friends can address this challenge.

6. The Fine-tuning Argument for the Multiverse without Double Counting

This section argues that it is at least in principle possible to motivate a non-negligible hypothetical prior $P(M)$ using empirical data D and to subsequently run the fine-tuning argument without double counting of R . The key idea is that, for suitable data D , there are generally parts or aspects D^* of D that do not entail R and may still be multiverse-supporting.

To see this, consider the following: suppose that we have indeed managed to acquire data D that help us motivate the ascription of a non-negligible $P(M)$. For the sake of the argument, let us suppose that, as Juhl suggests, these data D entail parts or all of R .

Now suppose further—without loss of generality—that D , specified in propositional form, is closed under deductive inference (alternatively, assume that D is the deductive closure of our multiverse-suggesting empirical data in propositional form). Generally, D will *not* be logically equivalent to R —even if D entails R —unless R entails all of D , for which, however, there seems to be no systematic reason. In general, there will be a non-empty subset D^* of D that is not entailed by R , i.e. is logically compatible with $\neg R$. As I argue below, it is possible for this D^* to be multiverse-supporting on its own.

To check whether D^* can legitimately be used to motivate a non-negligible hypothetical prior $P(M)$ we have to go back to the *ur*-probability approach to Bayesianism and consider a hypothetical agent who lacks the evidence R but has otherwise as much of our background knowledge as coherently possible. And whatever that background knowledge comprises—remember, we are considering an agent who, bizarrely, is unaware of her own existence—there seems to be no reason to doubt that it will include D^* . For, by assumption, we are aware of D^* and, by construction, D^* is not entailed by R . If it happens that D^* alone can be appealed to when motivating a non-negligible $P(M)$, then running the fine-tuning argument based on the so-motivated $P(M)$ does not involve any double counting and may potentially result in a sizeable $P^+(M)$.

Avoiding double counting along these lines is possible only if two conditions are met: first, the evidence R must not entail our multiverse-supporting data D (for otherwise D^* would be empty); second, D^* on its own—and not merely the full D —must be multiverse-supporting. Taken together, these two conditions boil down to the simple and intuitive requirement that, for the fine-tuning argument to result in rational belief in a multiverse, there must be *independent* empirical support for the multiverse over and above the finding that the parameters are right for life despite the required fine-tuning. Priors (or hypothetical priors) play no role in this requirement. This is an appealing feature because problems with double counting are not by themselves conceptually tied to difficulties with the assignment of (hypothetical) priors, so it makes sense that we can ultimately assess the double counting issue without considering specific (hypothetical) priors. What would really vindicate the double counting charge is an argument as to why there cannot possibly be any independent empirical support for the multiverse over and above the finding that the parameters are right for life despite the required fine-tuning.

It seems unlikely, though, that such an argument will be forthcoming. According to the popular account of inflationary cosmology sketched in section 4, our data about the cosmic microwave background (CMB) are confirmatory of inflationary cosmology, which in turn (at least indirectly) suggests that the landscape multiverse scenario might be correct. Clearly, not all aspects of the CMB data are entailed by R , notably not all those that are taken to support inflation. If the aspects of the CMB reported by Planck Collaboration (2014) that favour inflation were all entailed by R , scientists would have been able to predict them, based on R alone and without any help from inflationary cosmology. So we have here empirical data D^* , in this case concerning the CMB, which are part of our complete multiverse-suggesting data D but not entailed by R . Since these data D^* are confirmatory, on their own, of a multiverse-suggesting theory (inflation), they are (at least indirectly) multiverse-suggesting by themselves. If we use them to help motivating a non-negligible $P(M)$, we can run the fine-tuning argument for the multiverse based on the so-motivated $P(M)$, potentially resulting in a sizeable posterior $P^+(M)$, without committing double counting.

In case future developments in physics establish that the account of inflationary cosmology and the CMB data relied on here is incorrect, it would not damage the present claims. The empirical assumptions made are coherent, and this suffices to establish that it is in principle possible, given suitable data, to motivate a non-negligible $P(M)$ without implicitly relying on the finding that the parameters are right for life.

Juhl's *warning* of double counting is by no means superfluous, though. As we have seen, it is realistic that empirical data D appealed to when motivating a non-negligible prior $P(M)$ entail (parts of) the evidence R . In concrete cases, separating those bits of D that entail R from those that do not and establishing that the latter are multiverse-supporting on their own may well be an arduous task.

That it is in principle possible to motivate a non-negligible $P(M)$ independently of the appeal to the finding that the parameters are right for life does of course *not* entail that it is presently rational for us to actually believe in a multiverse, given the available evidence, fine-tuning as well as other. As outlined in section 2, the fine-tuning argument for the multiverse faces various open challenges that apply even if, as argued here, it can in principle be saved from the double counting charge. Notably, for the currently most popular multiverse scenario—the landscape multiverse sketched in section 4—it remains unclear whether it merits the ascription of a non-negligible prior. String theory, the scenario's second pillar beside inflationary cosmology, is not completely understood from a conceptual point of view and, more importantly, lacks any direct empirical support. Moreover, it has not been rigorously established whether the landscape multiverse, if it really exists, does include a universe with exactly the same laws and constants as our own in the first place. But unless we obtain really robust independent empirical evidence for some specific multiverse scenario, the argument from fine-tuning for the multiverse remains tentative at best.

Notes

1. For popular overviews of the fine-tuning for life of various constants, boundary conditions, and even laws of nature themselves, see Leslie (1989, ch. 2), Davies (1982), Rees (2000), and Lewis and Barnes (2016); for more technical ones see Hogan (2000, 2007) and Barnes (2012). For an up-to-date overview of suggested reactions to fine-tuning for life, see Friederich (2017). Constants, boundary conditions, and laws are collectively referred to as 'parameters' in what follows.
2. Carter's famous (weak and strong) *anthropic principles* (Carter 1974) remind us that this triviality may play an important role when assessing the impact of data concerning facts that are required to obtain for there to be observers. See Barrow and Tipler (1986), Earman (1987), Leslie (1989), McMullin (1993), and Bostrom (2002) for interpretation of the anthropic principles and the nuanced differences between them.
3. The main alternative to the Bayesian formulation is to frame the argument as an inference to the best explanation. Using Leslie's terminology (Leslie 1989, ch. 6) the candidate explanation in question would be an 'anthropic' one. It is controversial, however, whether anthropic 'explanations' really qualify as such (see Earman 1987, 309 for criticism). Since 'explanation' is such a complicated notion and recent research on the fine-tuning argument for the multiverse has overwhelmingly focused on the Bayesian formulation, the present paper follows that route.
4. Hypotheses according to which certain constants vary across one and the same universe count as multiverse scenarios in the sense of the present discussion. Current empirical evidence does not seem to support such hypotheses (Uzan 2003).

5. This worry is developed into a fully fledged objection against the fine-tuning argument for the multiverse (and against the fine-tuning argument for intelligent design) along varying lines by McGrew, McGrew, and Vestrup (2001), Colyvan, Garfield, and Priest (2005), and Juhl (2006).
6. Typicality considerations were pioneered by Carter (1974) and Leslie (1989). The typicality criteria most appealed to by physicists are Vilenkin's *principle of mediocrity* (Vilenkin 1995) and Bostrom's *self-sampling assumption* (Bostrom 2002). Typicality criteria can be regarded as indifference principles of *self-locating belief*: inasmuch as we are ignorant about who and where among observers we are, an assumption of typicality advises us to treat all possibilities as equally likely. A restricted indifference principle of self-locating belief that shares some implications with the aforementioned typicality criteria is Elga's *Indifference* (Elga 2004).
7. Matters are especially complicated if the reference class of observers is infinite because typicality criteria are then difficult to evaluate. This raises a thorny issue known as the *measure problem* of cosmology, see Schellekens (2013, section VI.B) for an introduction to this problem, Smeenk (2014) for a philosopher's sceptical assessment of its solvability, and Arntzenius and Dorr (2017) for a more optimistic perspective.
8. An alternative solution to the problem of old evidence, which would avoid this drawback, is the approach due to Garber (1983), in which Bayesian conditioning is applied not to the old evidence itself but rather to the insight that the theory or hypothesis in question—in our case the multiverse hypothesis—*entails* or, in other versions (e.g. Hartmann and Fitelson 2015), *explains* the old evidence—in our case the fine-tuning evidence. Applying Garber-style solutions to the fine-tuning argument is far from straightforward, though, because the general multiverse hypothesis M neither *entails* R nor uncontroversially *explains* it. It is far from evident how to stage the fine-tuning argument in a Garberian framework.
9. For this reason, we would also be reluctant to accept SD by inference to the best explanation. The problem of whether the multiverse hypothesis can be motivated independently of the fine-tuning considerations arises not only on the Bayesian formulation.
10. Monton argues that even for some appropriately chosen *general* 'Design' hypothesis D the rational posterior $P^+(D)$ will likely be very small if we construe the prior $P(D)$ as a hypothetical (or *ur-*) prior. Whether this is true or not, since D is more inclusive than SD , the posterior $P^+(SD)$ cannot be higher than the posterior $P^+(D)$.
11. One may think that some version of the Everett or 'many worlds' interpretation of quantum theory would be an even better example of an independently motivated multiverse theory. Quantum theory does indeed enjoy excellent empirical support and, according to proponents of the Everett interpretation, their view is preferable over alternatives in view of widely recognised criteria such as elegance and simplicity (see Wallace 2012 for a much more complete case). However, unless supplemented by some dynamical account of how and why the parameters would vary across Everettian 'worlds' (or 'branches'), Everettian quantum theory is not a multiverse scenario in the sense of the fine-tuning argument. There are, however, attempts to bring together Everettian quantum theory and multiverse theories in the sense of the fine-tuning argument (see e.g. Bousso and Susskind 2011).
12. As an anonymous referee points out to me, there are serious principled worries about the possibility to coherently combine string theory and inflation. See Steinhardt and Wesley (2009) for serious concerns.
13. See Schellekens (2013) for a helpful introduction to string theory and its motivation and Dawid (1982) for (controversial) methodological arguments for string theory with particular emphasis on the absence of compelling theoretical alternatives.
14. According to earlier claims (Steinhardt and Turok 2008), there are non-inflationary cyclic cosmological models which are as good in predicting the detected CMB fluctuations as inflationary models. However, according to Planck Collaboration (2014), the newest observations support inflationary models over cyclic ones. Further alleged explanatory achievements of inflationary cosmology include its supposed ability to account for otherwise puzzling cosmic coincidences, notably the so-called flatness, horizon and magnetic monopole

- problems of cosmology, reviewed in Guth (2000). For philosophers' (partly critical) assessments of these claimed achievements see Earman and Mosterin (1999) and McCoy (2015).
15. Juhl uses 'U' instead of 'T', which would lead to confusion with the single-universe theory U considered above.

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